A Numerical Framework for Modelling Coupled Non-Isothermal Compositional Two-Phase Flow and Geomechanics Processes in Subsurface Applications

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Abstract

Subsurface applications such as geo-energy extraction, CO_2 sequestration involve complex interactions between multiphase fluid flow, heat transfer, and geomechanical deformation. Accurately modeling these coupled processes is essential for predicting system behavior and optimizing operational strategies. This paper presents a coupled non-isothermal compositional two-phase flow and geomechanics model for representing the thermo-hydro-mechanical-compositional processes in subsurface applications. In order to improve the efficiency of numerical solutions, a hybrid numerical approach combining element based finite volume method (EbFVM) and finite element method (FEM) is used, in which EbFVM is used to spatially discretize mass and energy conversation equations, while linear momentum equilibrium equation is discretized with FEM. Two numerical approaches are coupled through sharing shape functions. Temporal discretization is achieved using an implicit mid-interval backward difference scheme. Reliability of the developed numerical framework is examined by verification tests against available analytical or published numerical solutions. And then the numerical model is applied to quantitatively investigate the efficiency of carbon dioxide storage and enhanced gas recovery. The effects of geological and engineering conditions are considered, including reservoir permeability, heterogeneity, injection strategies. The simulation results can provide valuable insights into of CO_2- enhanced gas recovery process, offering guidance for field-scale implementation.

Keywords

Numerical Model, Compositional Flow, Geomechanics, Geo-Energy, Hybrid Numerical Solution, Carbon Dioxide Storage